Magnetic Ground State of Industrial Sensors

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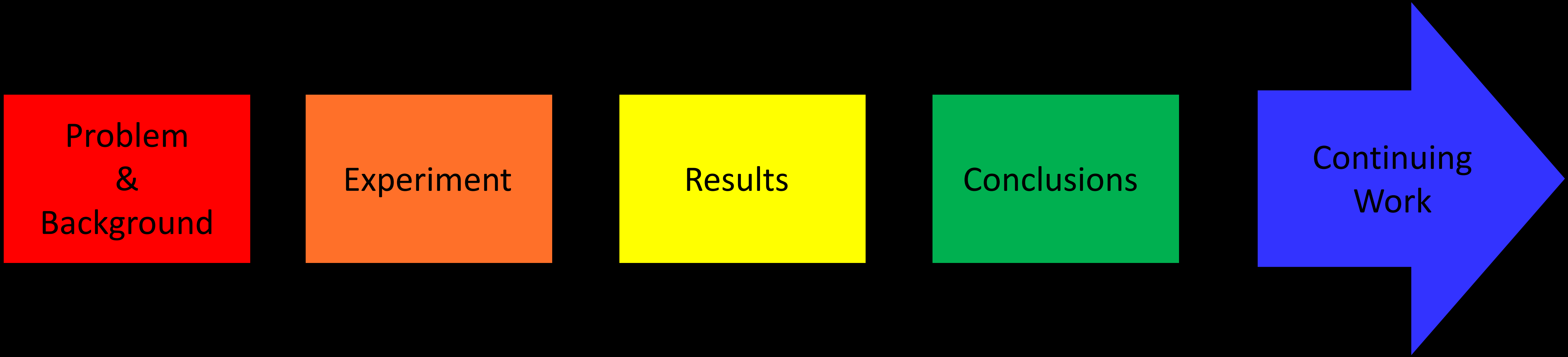
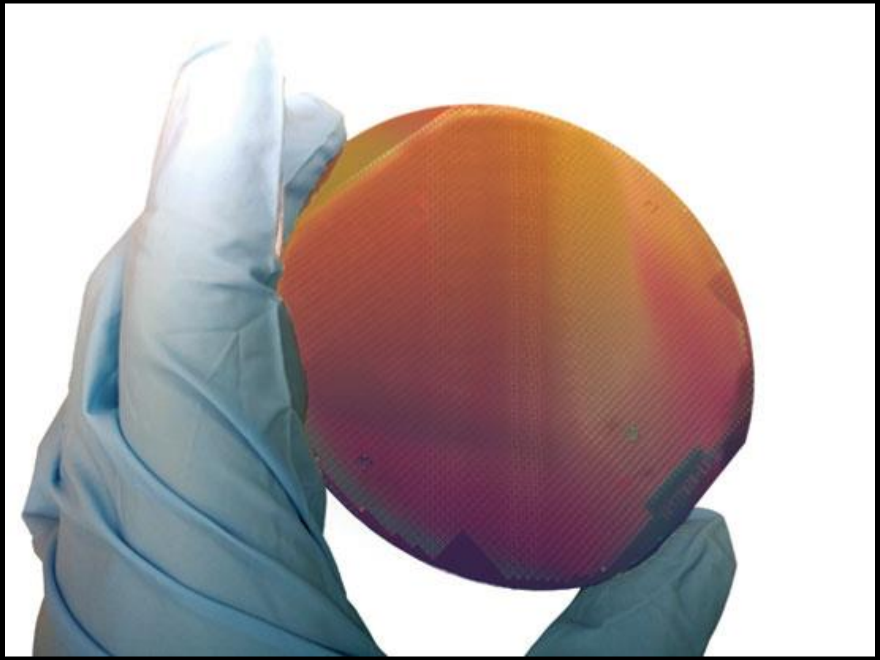
Dr. Joe Davies (NVE Industries)


Problem
&
Background
Experiment
Results
Conclusions
Continuing
Work

Background

wafer

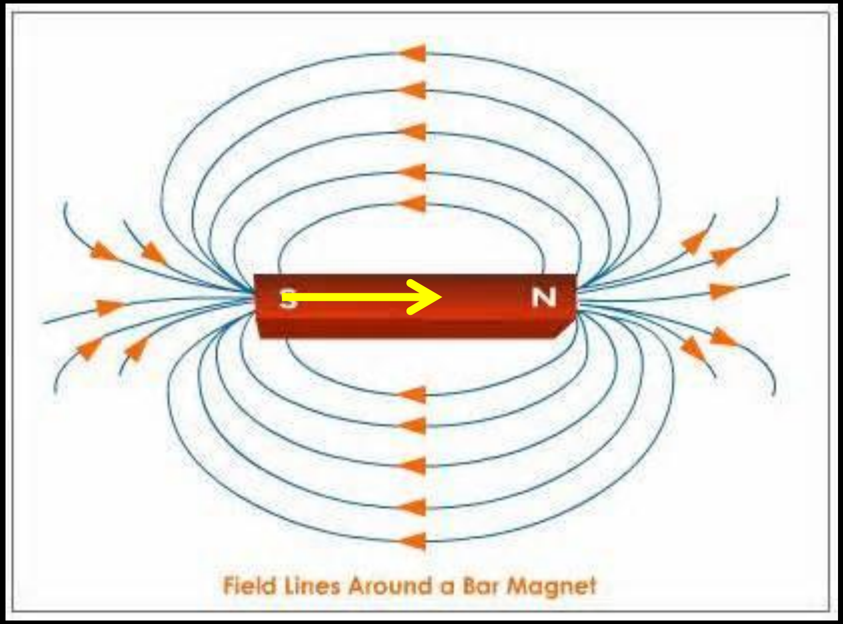


Indium.com

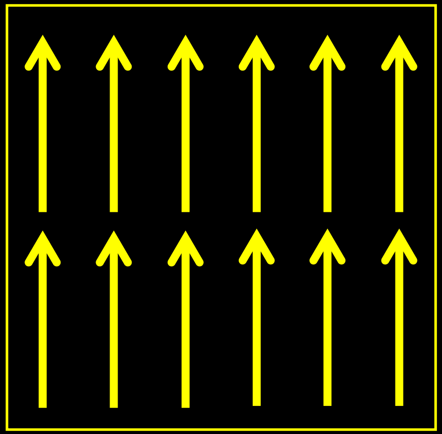
GMR sensor

Spinic.com

Magnetic particle

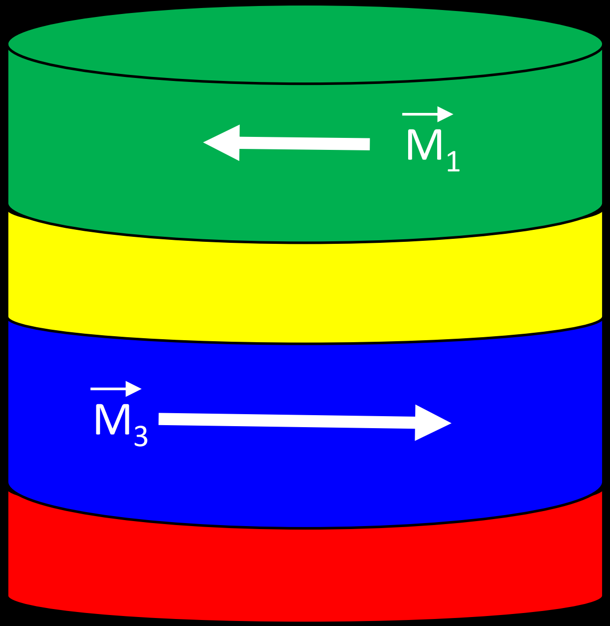


Ferromagnet



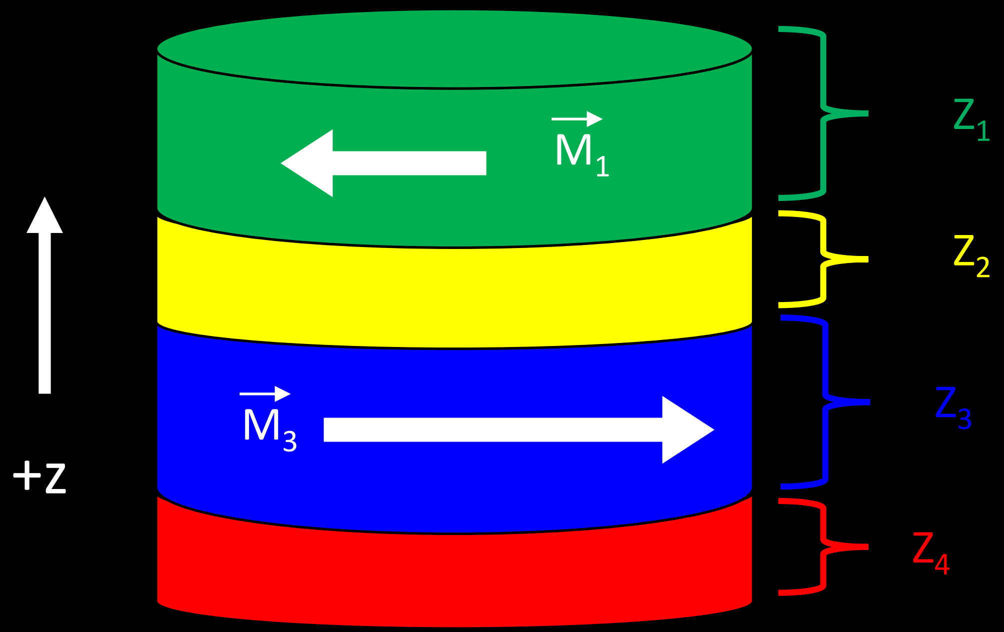
Synthetic anti-ferromagnet

AKA wafer

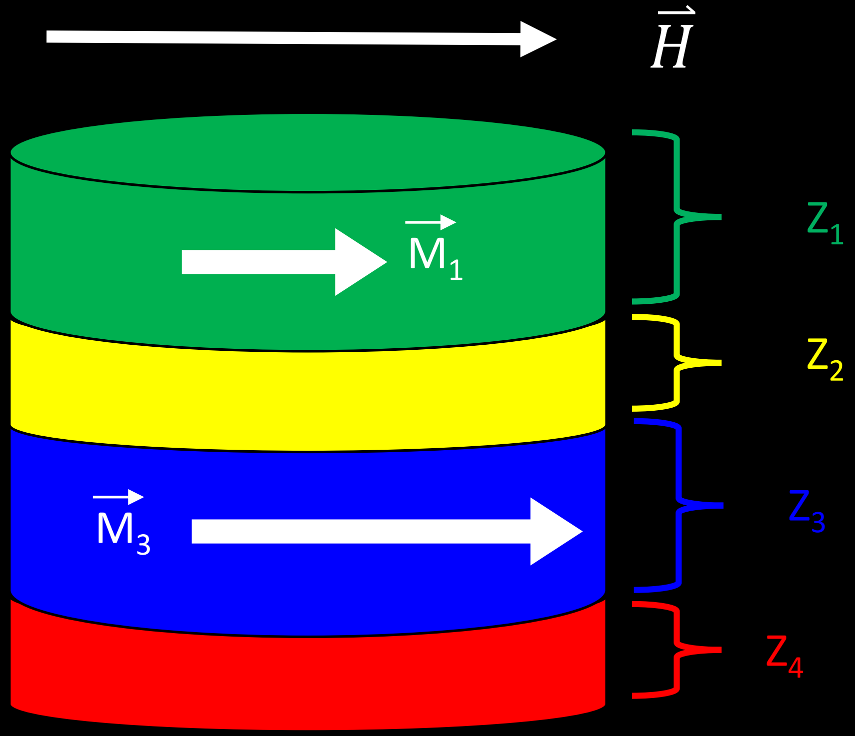


Purpose: Determine thickness and magnetization

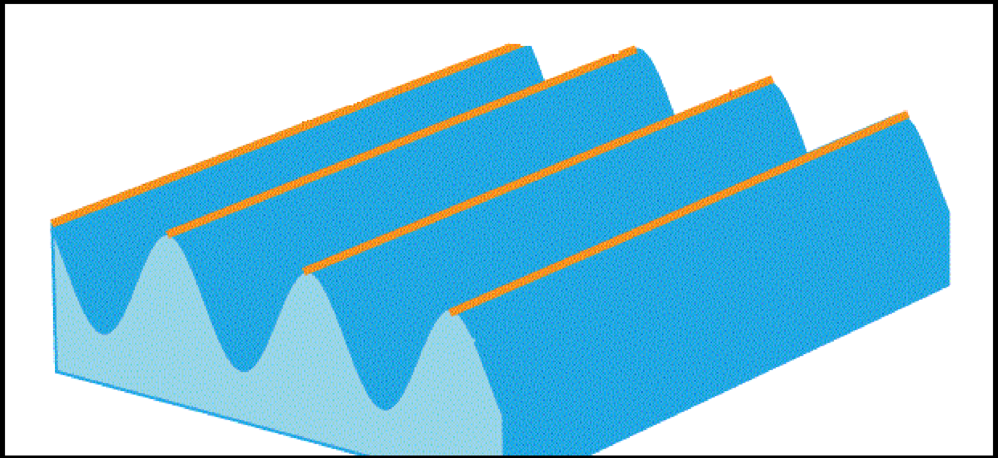
- No external magnetic field AKA ground state
- High resistance

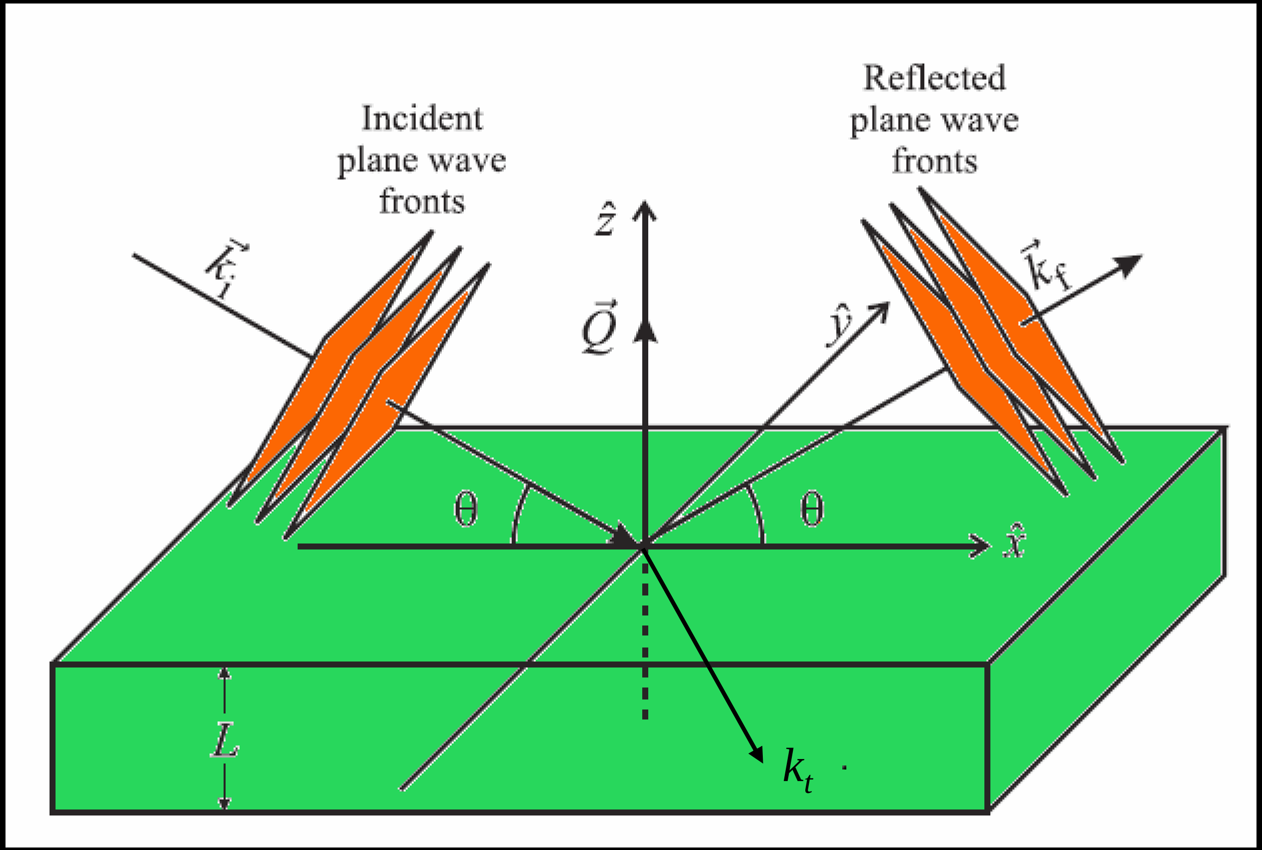


- External magnetic field
- Low resistance

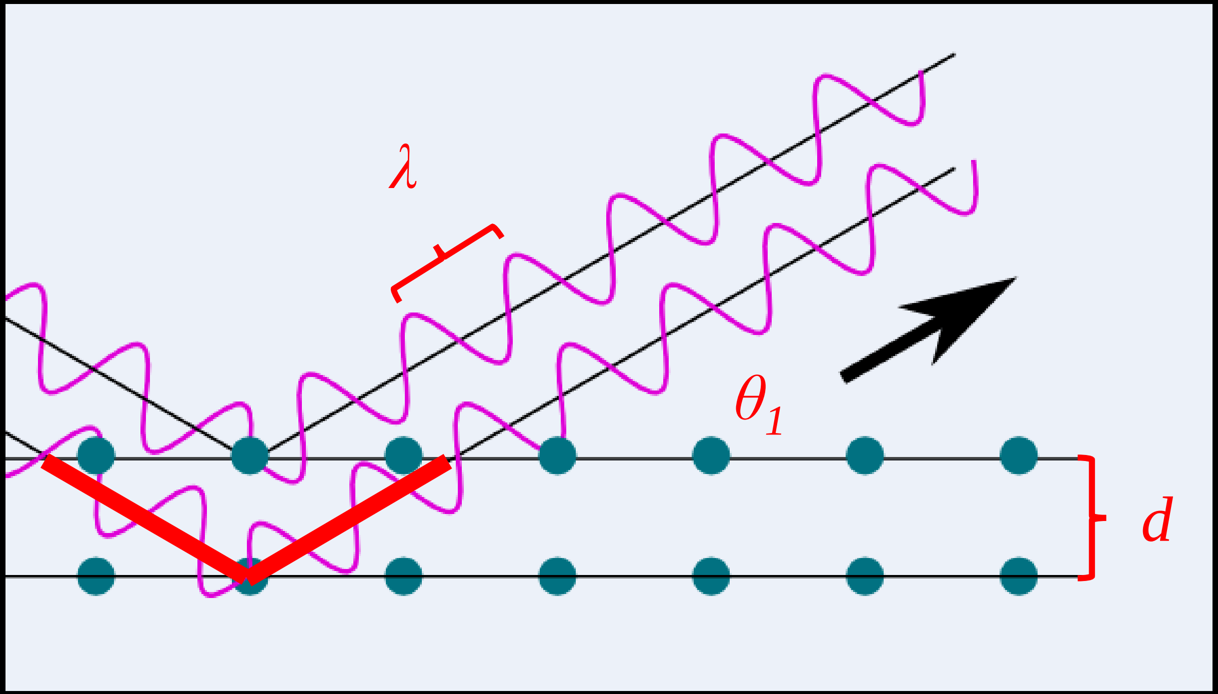


neutron wave





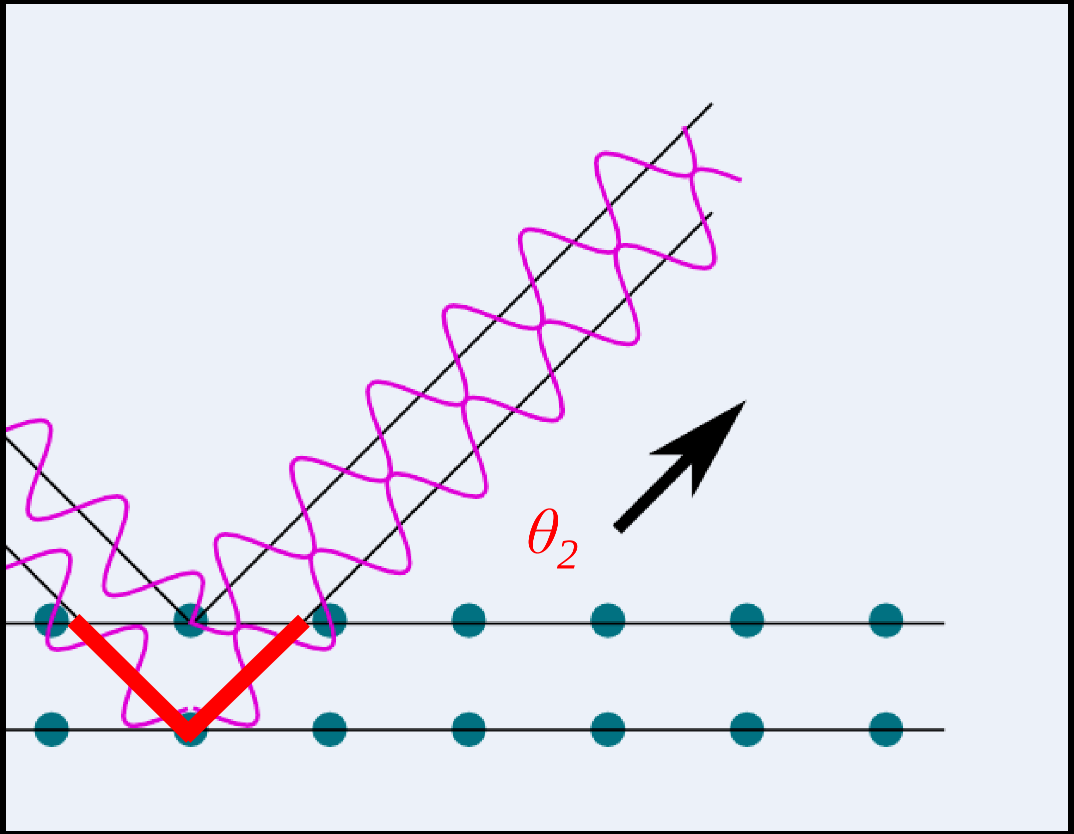
Constructive Interference



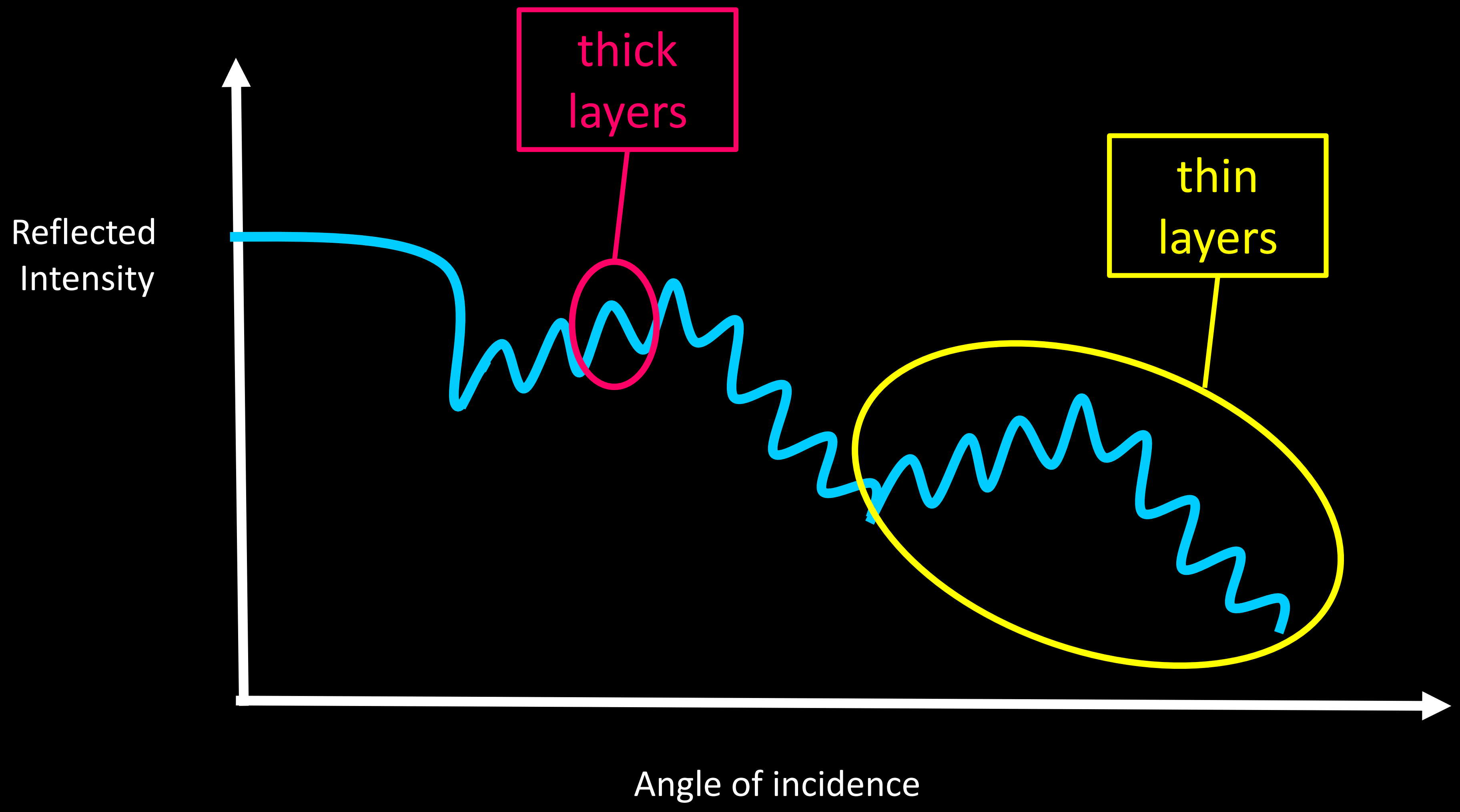
Bragg condition

$$n\lambda = 2d \sin\theta$$

Destructive Interference



Interference from layers of varying thickness



$$Q \equiv \frac{4\pi \sin\theta}{\lambda} = \frac{n2\pi}{d} \propto \theta$$

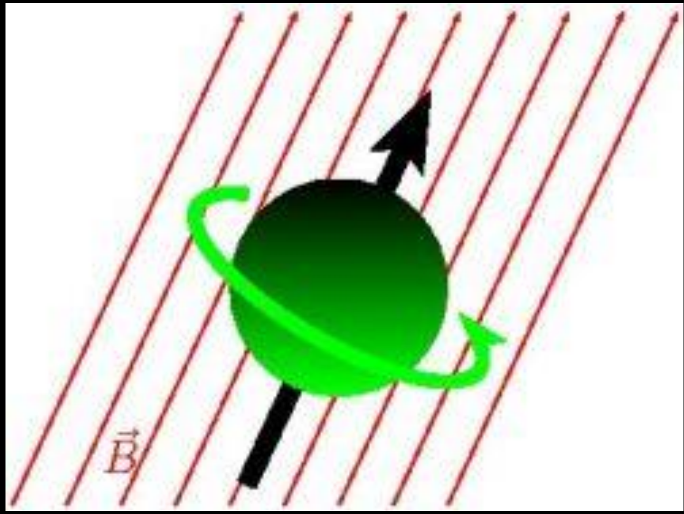
Order number of repeated feature

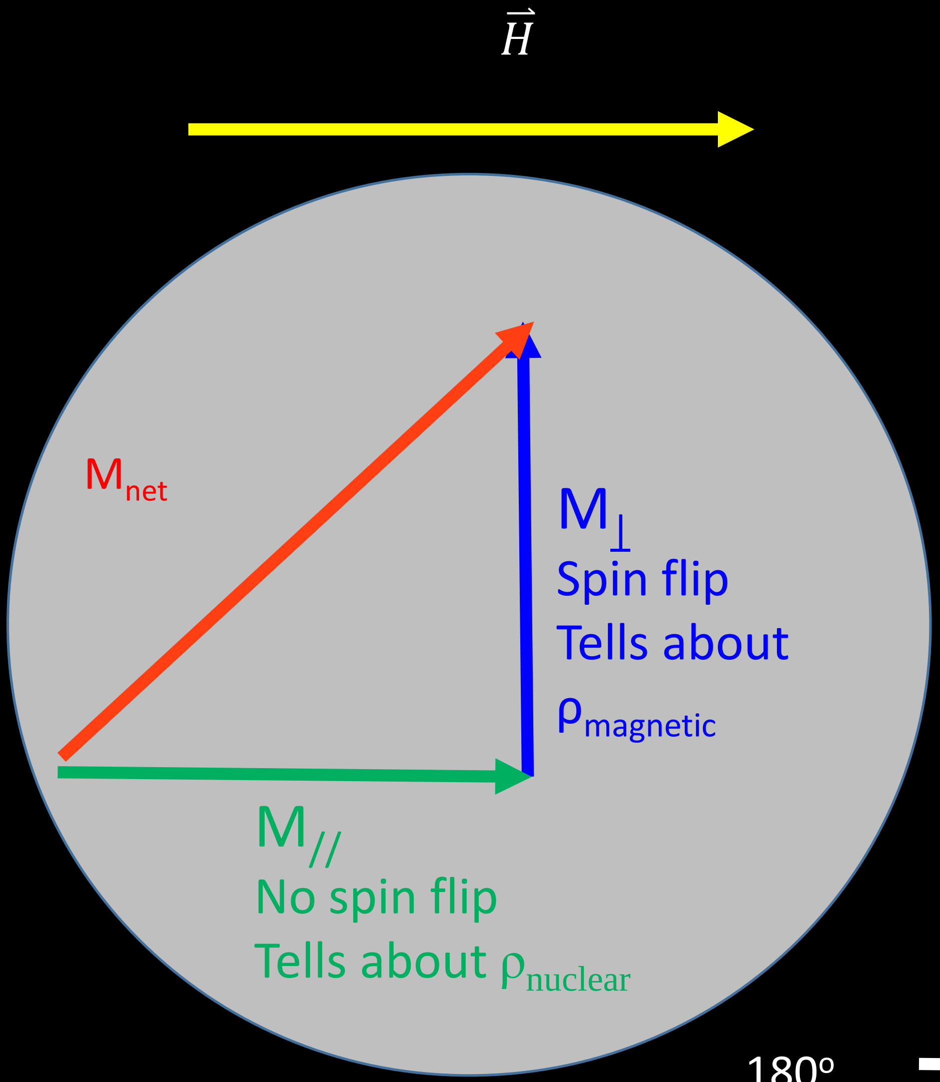
Thickness of repeated feature

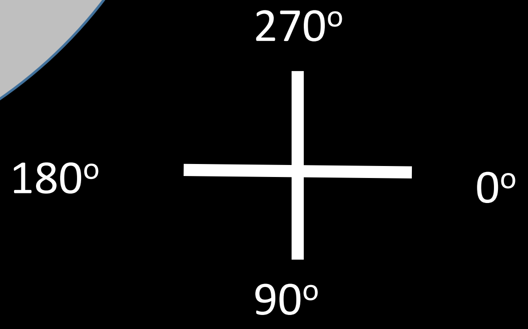
$$V = \frac{2\pi\hbar^2}{m} Nb = \frac{2\pi\hbar^2}{m}\rho$$

$$\rho = \rho_{nuclear} \pm \rho_{magnetic}$$

$$\vec{M} \propto \rho_{magnetic}$$

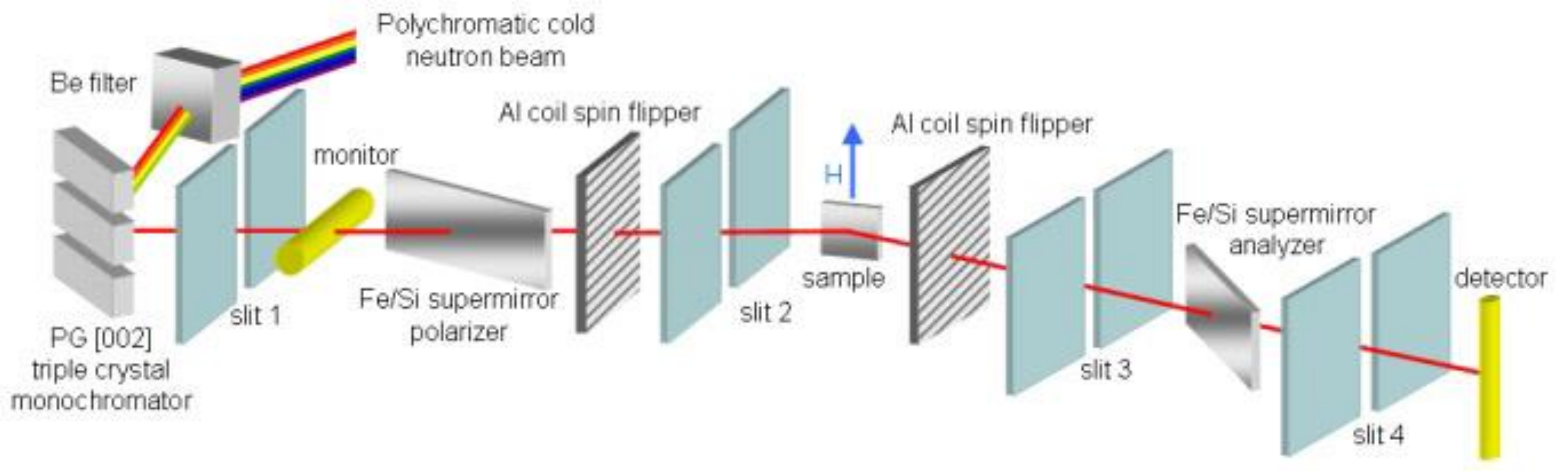




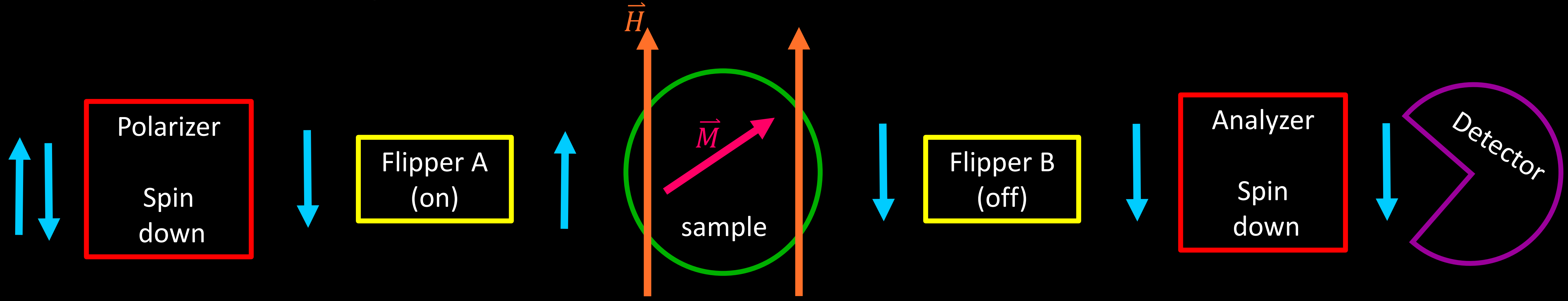


Top View of wafer

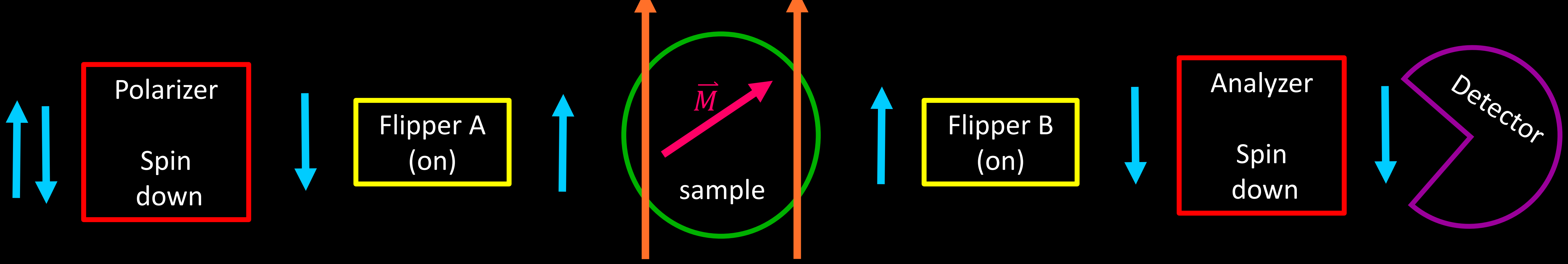
Experiment

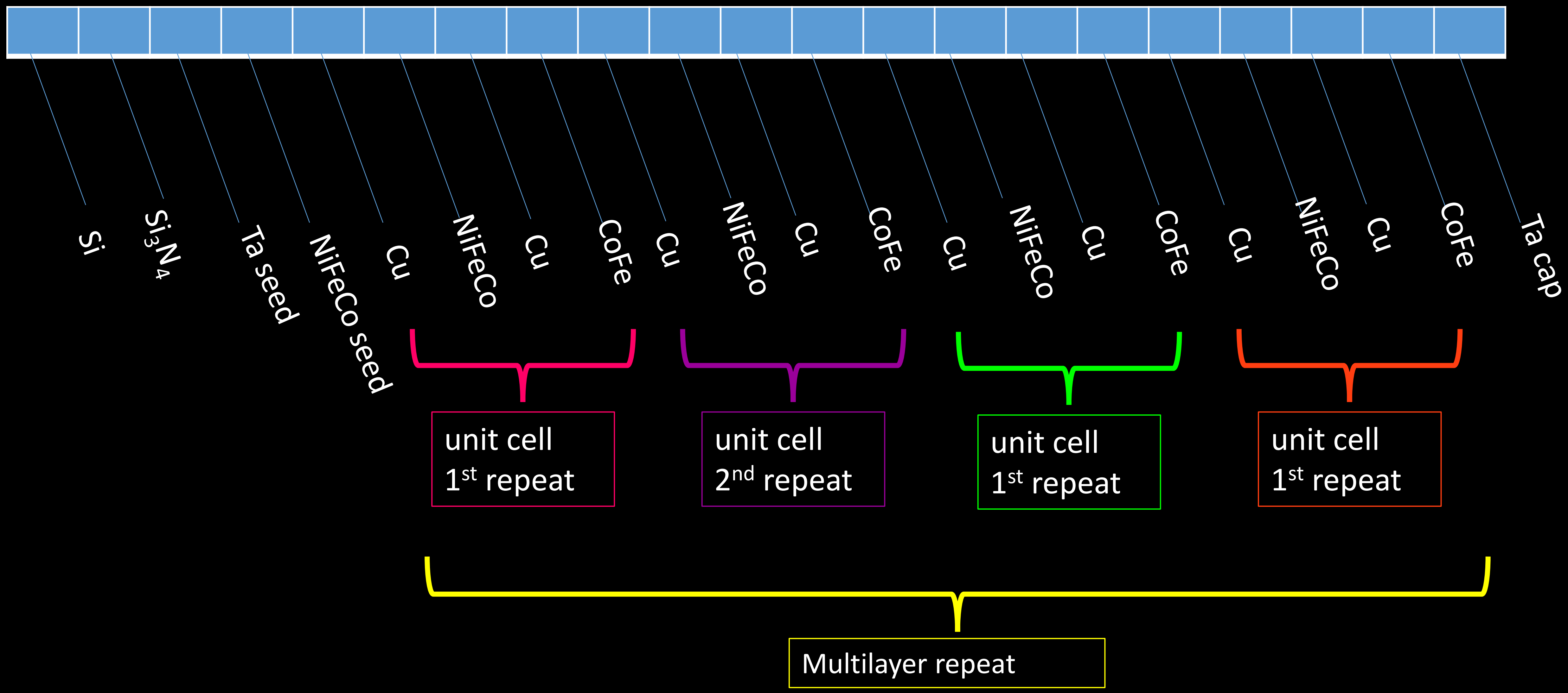

Polychromatic cold
neutron beam
Be filter
monitor
Al coil spin flipper
Al coil spin flipper
H
sample
Fe/Si supermirror
analyzer
detector
PG [002]
triple crystal
monochromator
slit 1
Fe/Si supermirror
polarizer
slit 2
slit 3
slit 4

Spin – flip scattering

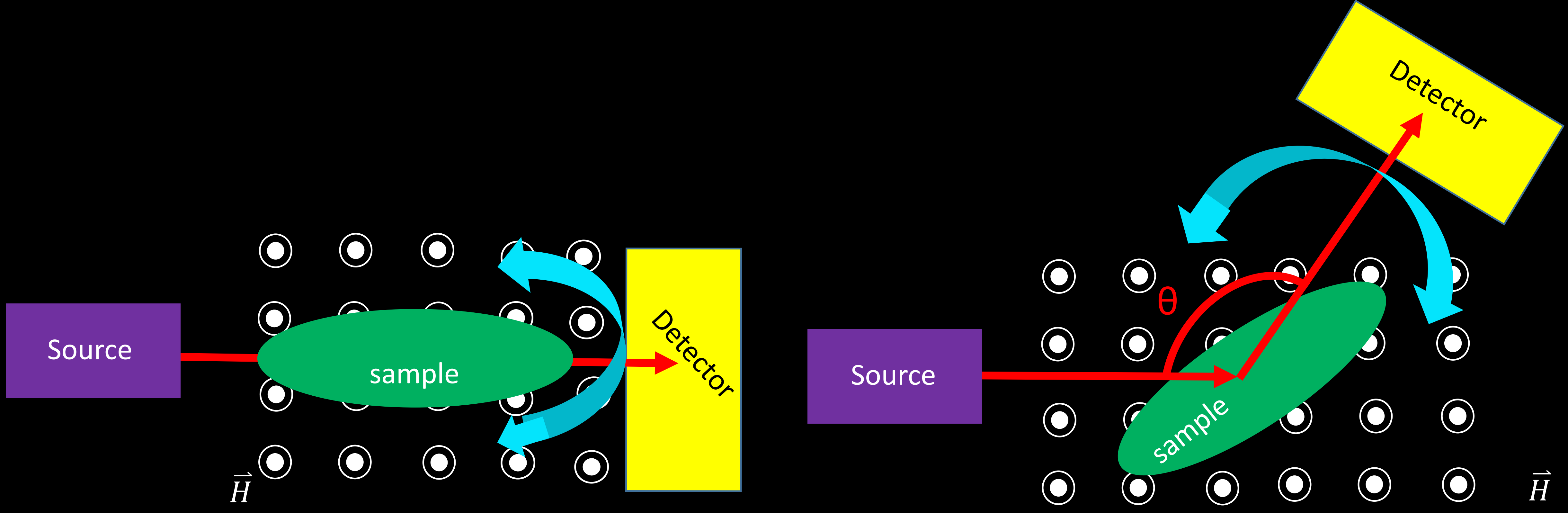


Non – spin – flip scattering





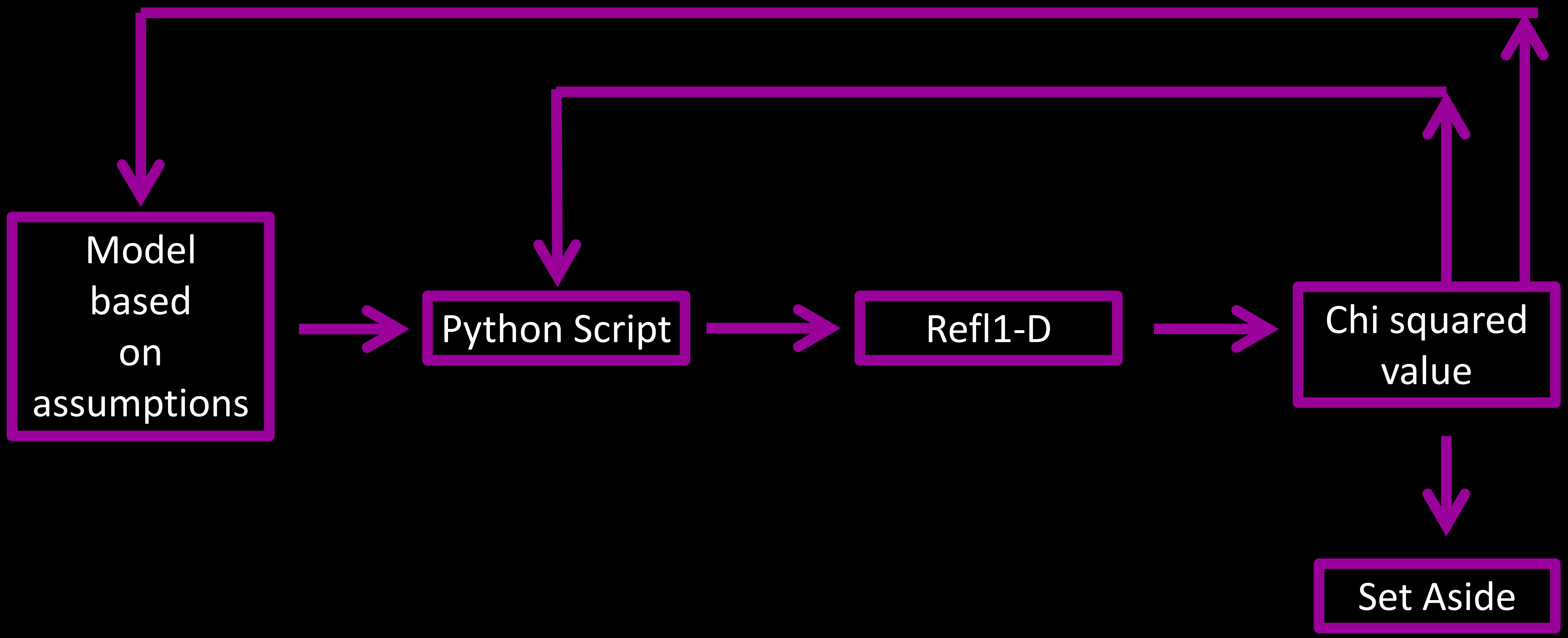
Si
Si_3N_4
Ta seed
NiFeCo seed
Cu
NiFeCo
Cu
CoFe
Cu
NiFeCo
Cu
CoFe
Cu
NiFeCo
Cu
CoFe
Cu
NiFeCo
Cu
CoFe
Ta cap
unit cell
1st repeat
unit cell
2nd repeat
unit cell
1st repeat
unit cell
1st repeat
Multilayer repeat



- Rotated the sample and detector angle in magnetic fields of 20 mT and 0.5 mT
- Detector measured the intensity of the reflected neutrons as a function of sample angle over time

Results
&
Conclusions

Data Analysis Process

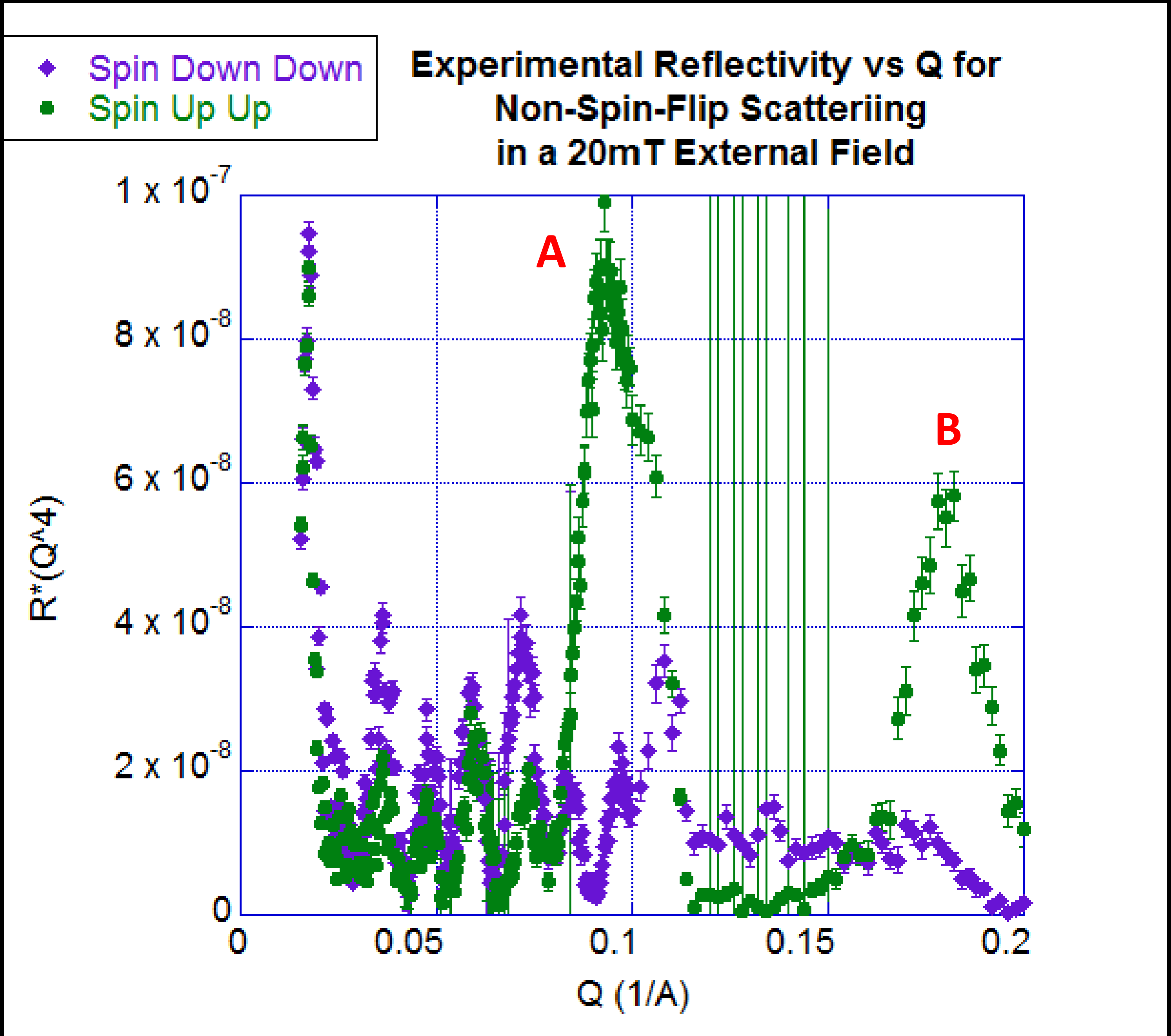


Experimental Data at High Field

$$Q_A = \frac{2\pi}{d}$$

$$Q_B = \frac{4\pi}{d}$$

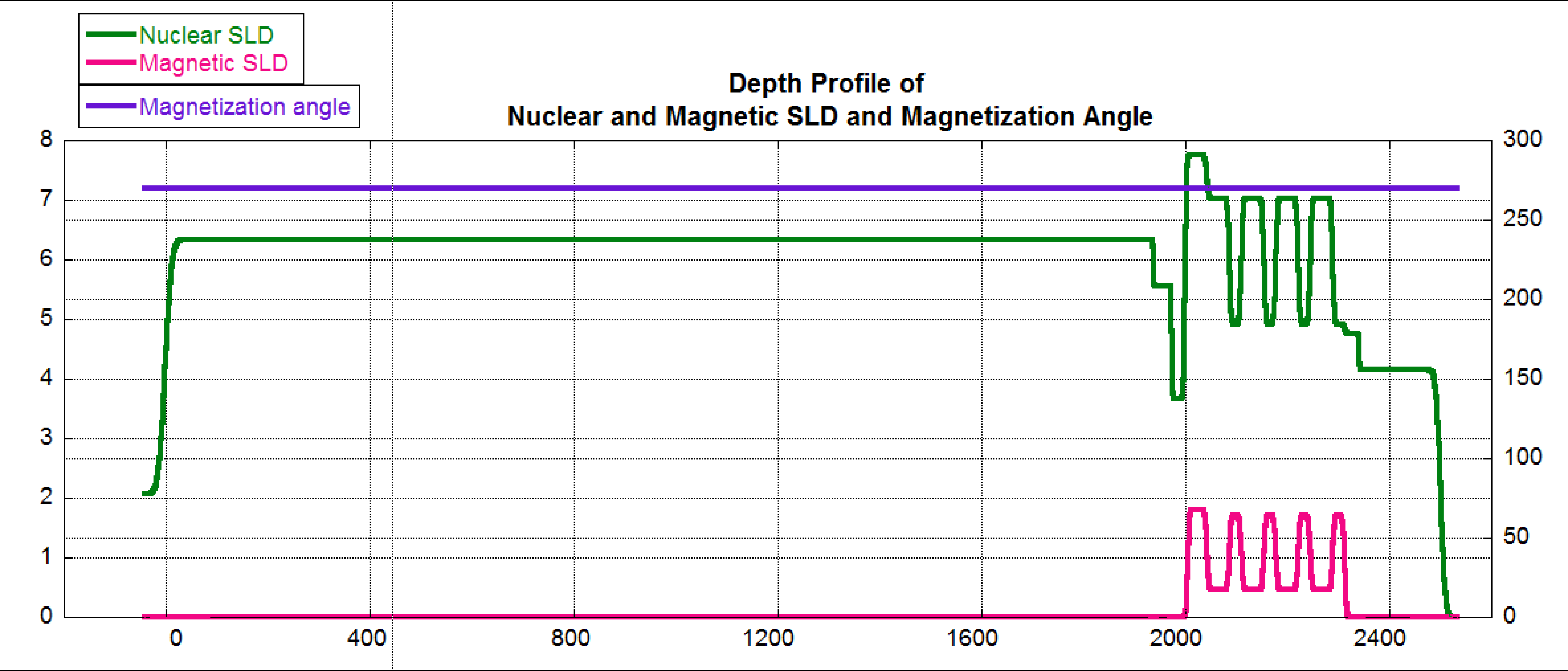
$\longrightarrow$ $\bar{d}_{actual}$= 68 A



Best Model at High Field

Scattering Length Density

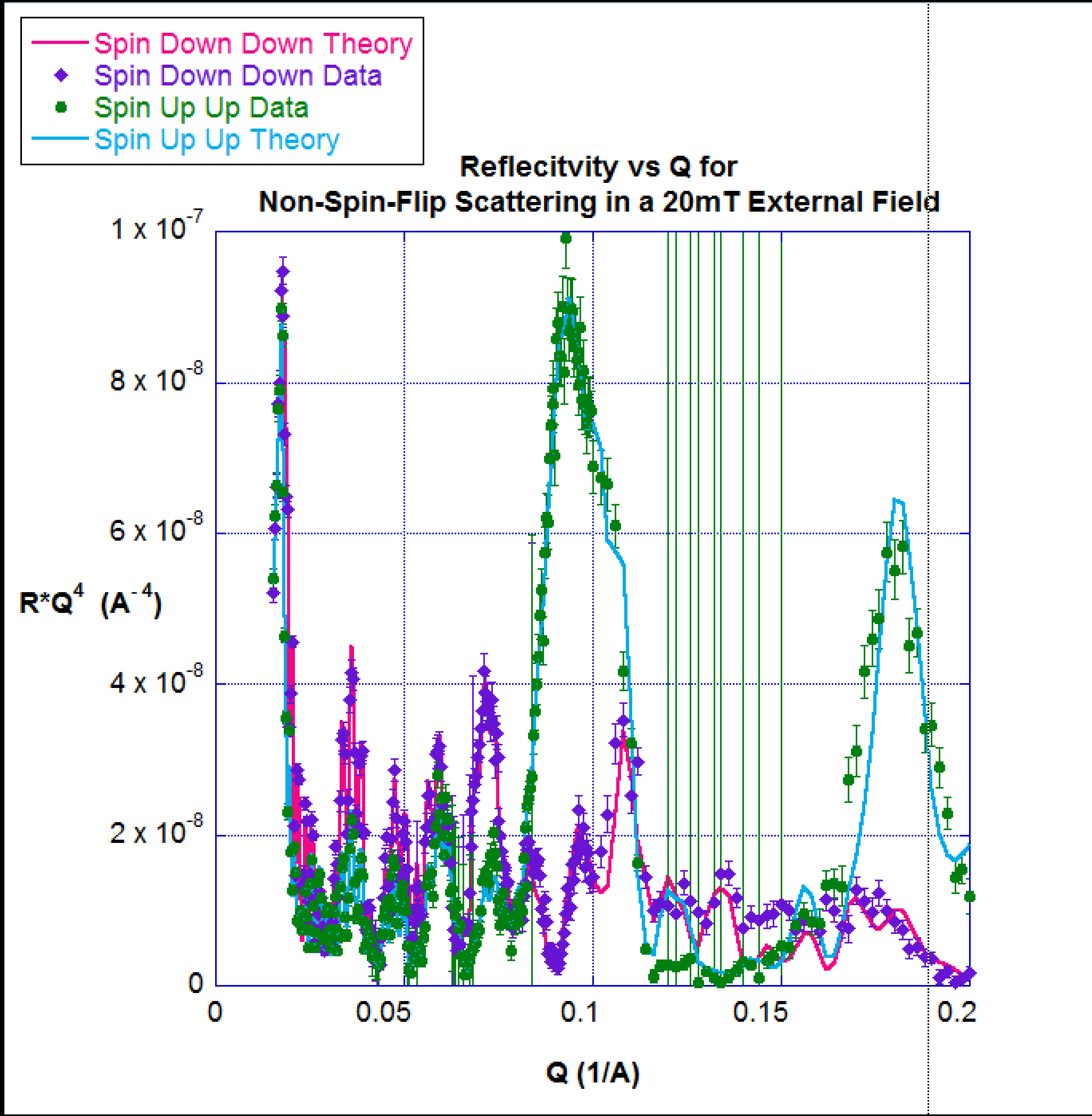
x 10 $^{-6}$ (A^{-2})



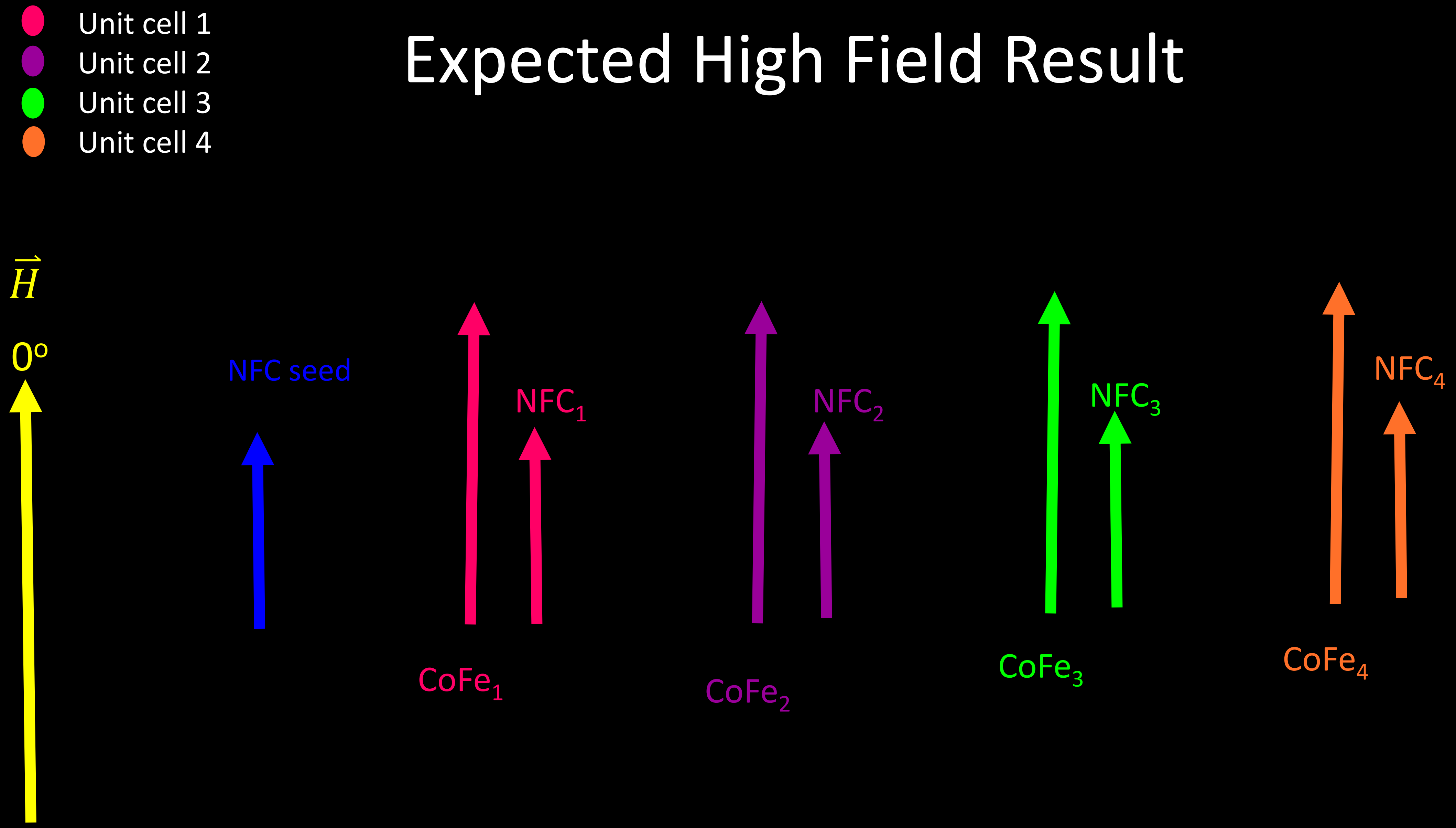
θ_M (°)

depth (A)

Best Fit at High Field

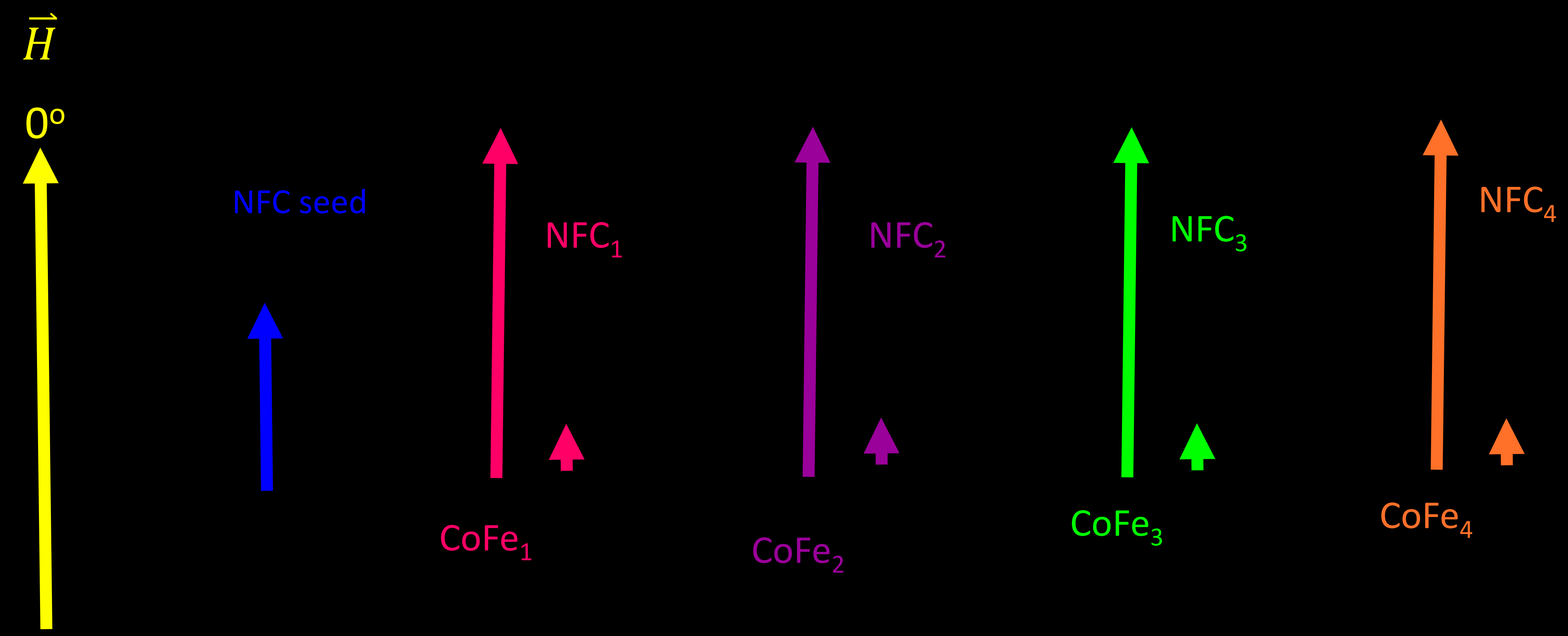


Expected High Field Result

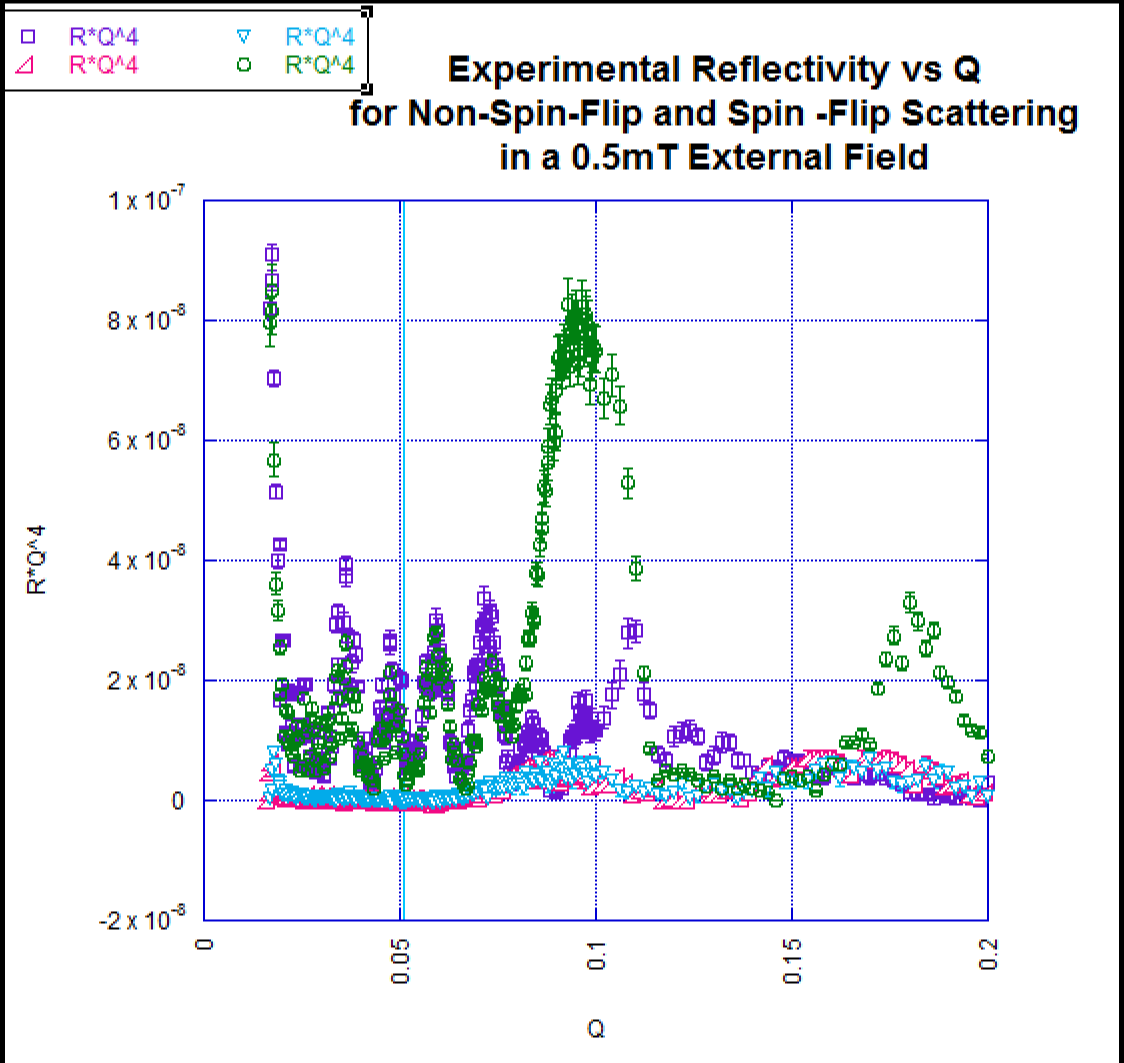


Unit cell 1
Unit cell 2
Unit cell 3
Unit cell 4

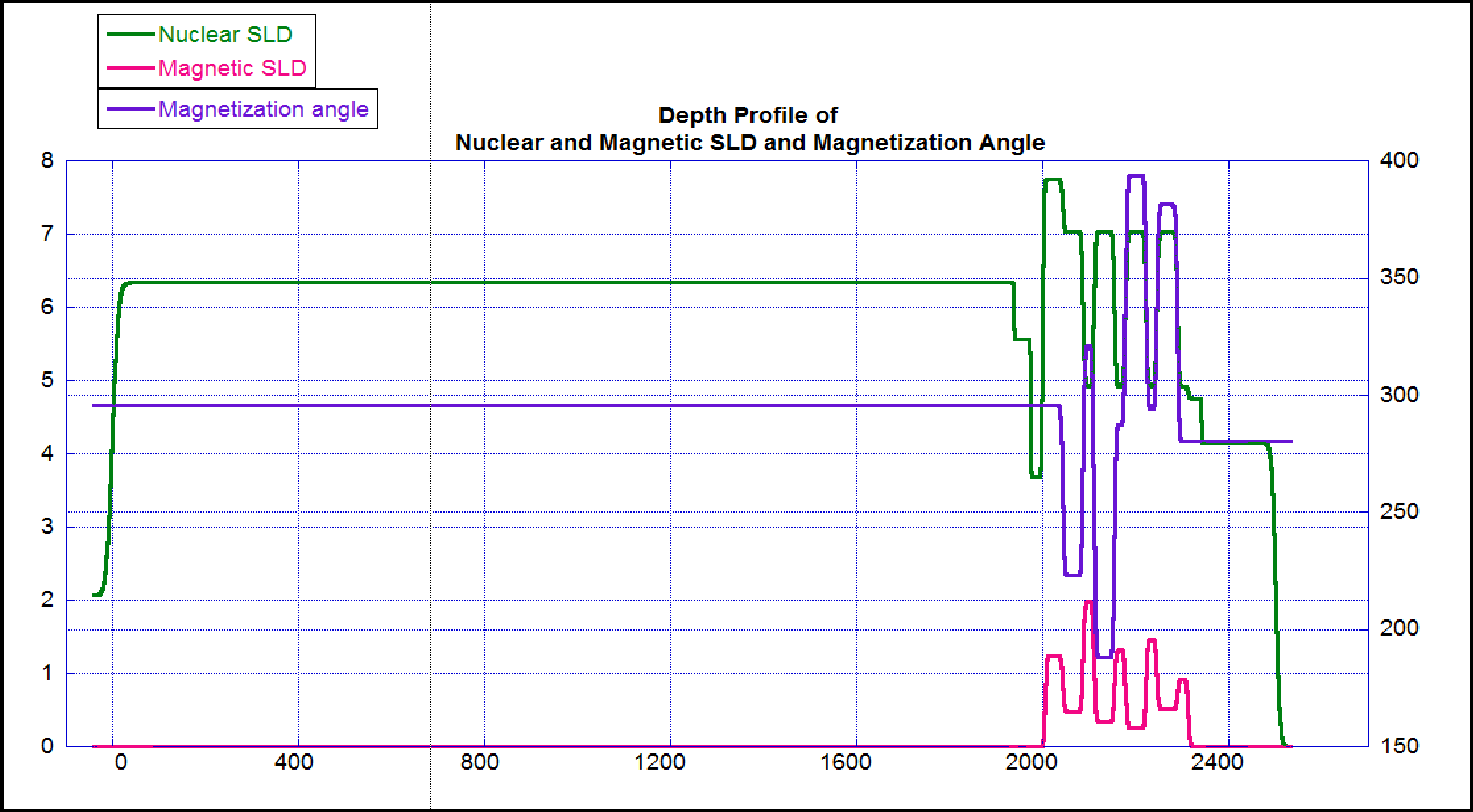
Actual High Field Result



Experimental Data at Low Field



Best Model at Low Field



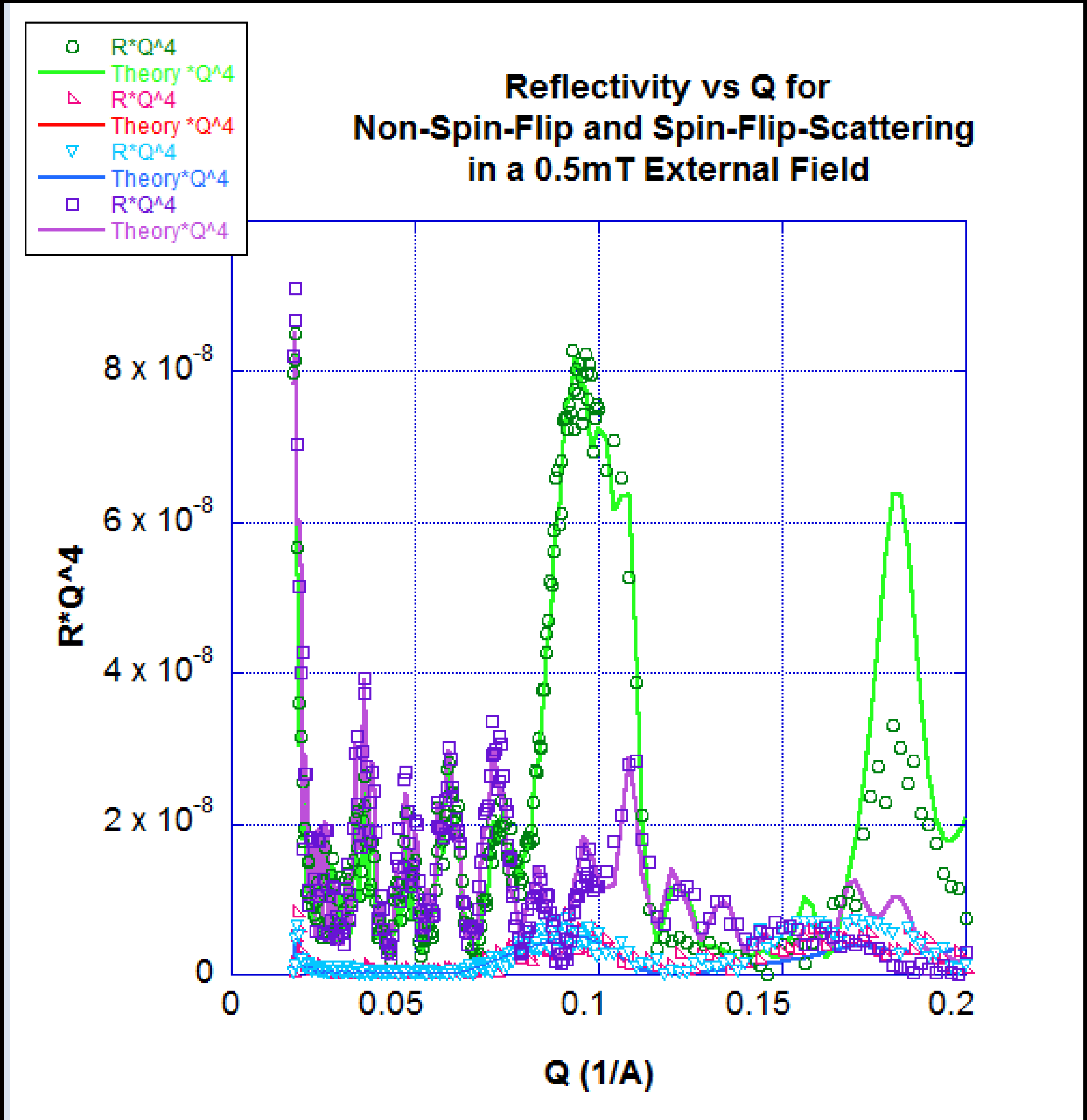
Scattering Length Density

x 10^{-6} (A^{-2})

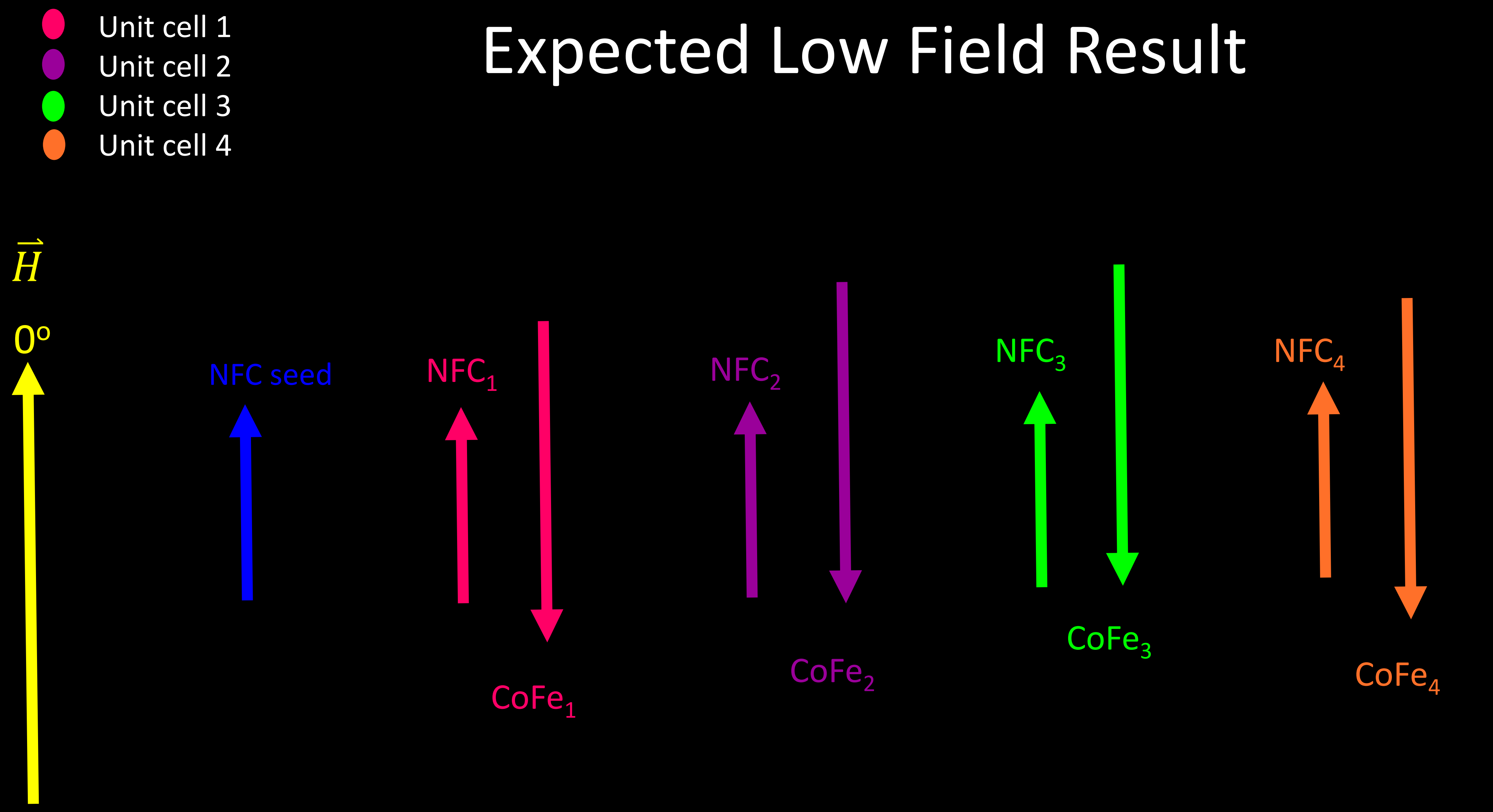
Magnetization Angle (°)

depth (A)

Best Fit at Low Field

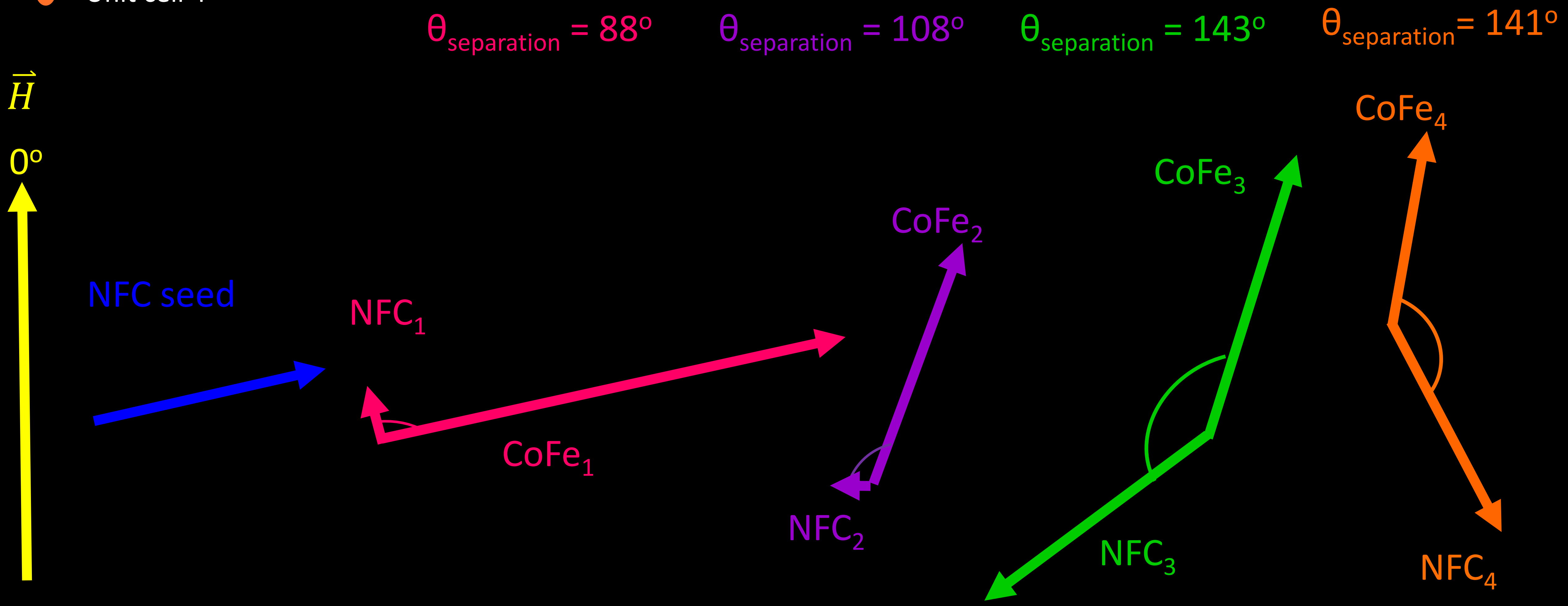


Expected Low Field Result



Actual Low Field Result

Unit cell 1
Unit cell 2
Unit cell 3
Unit cell 4



θ_M angles are measured relative to H field

Continuing Work

Why aren’t the magnetic layers coupling anti-ferro-magnetically at low field?

Acknowledgments

- SURF Program at NIST
- Dr. Brian Kirby (NIST)
- Dr. Alex Grutter (NIST)
- Dr. Julie Borchers (NIST)
- SURF directors
- NCNR staff
- Dr. Joe Davies (NVE Industries)
- Juniata College